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## **RELIABILITY OF EXPLOSIVE SQUIBS USED IN FIRE DELUGE SYSTEMS**

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John R. Hawk

Airbase Technologies Division  
Air Force Research Laboratory  
139 Barnes Drive, Suite 2  
Tyndall Air Force Base, FL 31403-5323

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14. ABSTRACT The purpose of this test and evaluation project was to collect success/failure rate data on 129 explosive actuators, like those used in the Advanced Fire Protection Deluge System (AFPDS), that had been stored for a number of years. The manufacturer specifies a shelf life for the actuators of 10 yr when stored at 68 °F and 2 yr when stored at 122 °F. The actuators were stored in a non-climate controlled earth covered magazine structure in which temperature was between 68 °F and 122 °F several months every year for up to 8 yr 4 mo. For testing, the actuators were subjected to electrical current above the minimum recommended. All 129 actuators detonated. Results indicate that explosive actuators stored at temperatures between 68 °F and 122 °F for up to 8 yr 4 mo have at least 94 % reliability. This information can be used in probabilistic risk analysis calculations by organizations with facilities equipped with high-speed explosive suppression and fire extinguishing systems that use these actuators.					
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## **Introduction**

The Fenwal<sup>®</sup> fire protection deluge sphere has been used for a number of years by Fire Researchers at the Air Force Research Laboratory (AFRL) in its Advanced Fire Protection Deluge System (AFPDS). The AFPDS is an ultra high speed fire suppression system that has been installed at several munitions manufacturing and inspection facilities. The Fenwal device uses a small pellet, or squib, of pentaerythritol tetranitrate (PETN) explosive to open a burst disk in the sphere that allows a fire suppression agent to flow. Fenwal specifies a shelf life for the squibs of 10 yr when stored at 68 °F and 2 yr when stored at 122 °F.<sup>i</sup> The squibs used by AFRL were stored on Tyndall Air Force Base, Florida in a military explosives storage facility, a non-climate controlled earth covered magazine structure typical of the manner in which they would be stored at munitions handling facilities employing the AFPDS. The purpose of this test and evaluation project was to collect success/failure rate data on a number of squibs that had been stored for a number of years at temperatures above 68 °F.

## **Methods, Assumptions, and Procedures**

The approach was to apply a current greater than the minimum specified by the manufacturer to the squibs, record the number of successes (detonations) and failures (non-detonations), and then to analyze the data and make predictions about reliability. Squibs that detonated on the first attempt were counted as successes. Squibs that did not detonate on the first attempt and for which no obvious cause could be identified were counted as failures. Squibs that did not detonate on the first attempt for any apparent cause but did on the second attempt were to be noted but not counted as successes.

Detailed information about temperature in the storage facility is unknown. Average high temperatures for the local area vary from 63 °F in January to 90 °F in July and August. Average low temperatures for the local area vary from 42 °F in January to 75 °F in July and August. The highest temperature on record for the area is 102 °F.<sup>ii</sup> Because the storage facility is partially covered with earth, interior temperatures are more moderate than the surrounding ambient temperatures, but for several months every year the temperature inside the storage facility was assumed to be above 68 °F. Dates of manufacture for the squibs ranged from late July 2003 to mid-November 2004, and so the ages of the squibs when tested ranged from about 7 yr 0 mo to 8 yr 4 mo. Fenwal specifies a shelf life for the squibs of 10 yr when stored at 68 °F and 2 yr when stored at 122 °F.

Each of the Fenwal squibs was marked with a six-digit date of manufacture code:

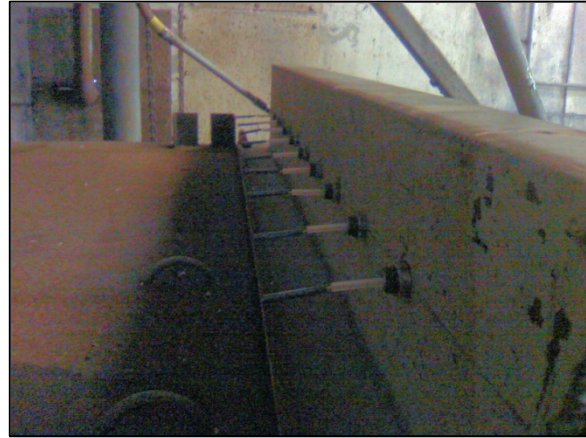
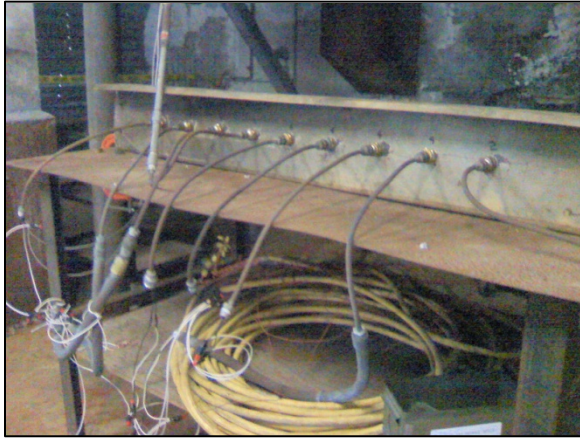
200445  
year week



Fenwal Explosive Actuator (Squib).

Fifty-five 0.80-g 4-pin squibs and seventy-four 0.45-g 2-pin squibs were tested. Three 12 V-lead acid batteries were connected in series and provided current to five 2-pin and four 4-pin squibs through a manual toggle switch. The nine squibs were connected in parallel. Resistance of the circuit including the squibs was  $1.2 \pm 0.1 \, \Omega$  and line voltage was 37.2 V. Average current to each squib was 3.4 A. The manufacturer's minimum recommended firing current is 1.5 A. Voltage was applied for about 1 s.

This was a binary (go/no-go) test, and the results were analyzed using a cumulative binomial distribution nomograph.<sup>iii</sup> The pass/fail ratios (reliability) of the squibs were calculated and analyzed by size (0.45 g or 0.80 g) and by date of manufacture. Reliabilities were calculated at 95 % and 99.6 % confidence levels.



Test Fixture Showing Actuator Cables Attached to Squibs (l) and Explosive Pellets Protruding from the Back (r).

## **Results and Discussion**

The following table shows a summary of the results. All of the 129 squibs detonated normally. For all squibs of 8 yr to 8 yr 4 mo since manufacture, the pass/fail ratio was 89/0. Reliability of the squibs at a 99.6 %-percent level of confidence (practical certainty) was 94 %, and the reliability at a 95 % level of confidence was 97 %. This means that in any 100 squibs 8 yr to 8 yr 4 mo old chosen at random it is practically certain that no more than six of the 100 would fail, and there is only a 5 % probability of up to three out of 100 failing. Similar results are shown in the following table categorized by time since manufacture and explosive weight.

	Reliability				Reliability					
	0.45 g (2-pin)			Total 2-pin	0.80 g (4-pin)				Total 4-pin	Total all squibs
Date Code	200334	200338	200445		200330	200331	200336	200337		
Age	8 yr 3 mo	8 yr 2 mo	7 yr 0 mo	-	8 yr 4 mo	8 yr 4 mo	8 yr 3 mo	8 yr 2 mo	-	-
Pass/Fail Ratio	10/0	24/0	40/0	74/0	1/0	14/0	20/0	20/0	55/0	129/0
95 % confidence	75 %	88 %	93 %	96 %	-	81 %	86 %	86 %	95 %	98 %
99.6 % confidence	57 %	76 %	86 %	92 %		66 %	75 %	75 %	90 %	95 %

## **Conclusions and Recommendations**

Results of this evaluation indicate that Fenwal explosive actuators stored in conditions similar to those in a magazine with external ambient temperature similar to those at Tyndall Air Force Base Florida for up to 8 yr 4 mo could have at least 94 % reliability. This information could be used in probabilistic risk analysis calculations by Fenwal and by organizations with facilities equipped with high-speed explosive suppression and fire extinguishing systems that use Fenwal actuators, with the understanding that exact storage temperatures for this experiment were unknown. The data should also be added to Fenwal's reliability records to create a larger database for statistical analysis.

<sup>i</sup> Fenwal Safety Systems. Drawing number 32-099932-008, revision BB, sheet 1 of 1. Marlborough, MA. October 2000.

<sup>ii</sup> The Weather Channel (online). Monthly Averages for Panama City/Tyndall AFB, FL.  
<http://www.weather.com/weather/wxclimatology/monthly/graph/USFL0394> (accessed November 30, 2011).

<sup>iii</sup> Defense Acquisition University. Program Managers e-Tool Kit, Test and Evaluation Nomograph.  
<https://acc.dau.mil/CommunityBrowser.aspx?id=294528> (accessed November 30, 2011).